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Original article

# Association between hip abductor function, rear-foot dynamic alignment, and dynamic knee valgus during single-leg squats and drop landings

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**Abstract**

*Background*: Preventing anterior cruciate ligament (ACL) injuries is very important for athletes, and dynamic knee valgus is considered a risk factor for non-contact ACL injury. However, little is known about whether the functions of the hip abductor and rear-foot increase dynamic knee valgus. A two-dimensional (2D) video-based screening test focused on hip abductor and rear-foot functions among factors involved in dynamic knee valgus. The present study determined associations between hip and rear-foot dynamic alignment and dynamic knee valgus.
*Methods*: This cross-sectional study recruited 130 female basketball players (258 legs) from nine high-school teams. The players performed single-leg squats and single-leg drop landings to provide knee-in (KID) and hip-out (HOD) distances on 2D video images. Hip and rear-foot dynamic alignment was evaluated using a dynamic Trendelenburg test (DTT) and a dynamic heel-floor test (HFT).
*Results*: The Chi-square test revealed no significant difference in the prevalence of DTT-positivity between single-leg squats (28.7%) and single-leg drop landings (23.3%). The prevalence of HFT-positivity was significantly greater during landings (51.4%) than during single-leg squats (31.0%, $p < 0.01$). The KID values for both single-leg squats and single-leg drop landings were greater in the DTT-positive than in the DTT-negative group (15.1 ± 5.4 cm and 20.2 ± 7.5 cm, $p < 0.001$). The HOD values were similarly greater in the DTT-positive group (15.2 ± 1.9 cm and 17.6 ± 2.8 cm, $p < 0.001$). The KID values for both single-leg squats and single-leg drop landings were greater in the HFT-positive than in the HFT-negative group (12.2 ± 5.1 cm, $p < 0.01$; 14.7 ± 7.2 cm, $p < 0.001$), whereas HOD values for these tasks did not significantly differ between the two groups.
*Conclusion*: Dynamic hip mal-alignment might be associated with both greater KID and HOD, whereas rear-foot eversion is associated only with greater KID. Hip abductor and rear-foot dysfunction are important factors for dynamic knee valgus and thus evaluating DTT and HFT will help to prevent dynamic knee valgus.


*Keywords:* 2D screening test; ACL injury; Dynamic alignment; Hip abductor and rear-foot function; Prevention

## 1. Introduction

A high proportion of anterior cruciate ligament (ACL) injuries occur during sports activities. Over 70% of all ACL injuries sustained while playing basketball are non-contact and occur while landing from jumps, or while rapidly stopping and changing direction without direct body contact.[1,2] The incidence of ACL injury is three- to five-fold higher among female than male athletes,[3,4] and the peak age of ACL injury in females is 16 years.[5] Typical non-contact ACL injuries comprise a combination of knee valgus, slight flexion and a posterior shift in the center of gravity.[6−8] A prospective study of 205 female adolescent athletes by Hewett et al.[9] identified knee abduction angles and moments as reliable predictors of ACL

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injury using three-dimensional (3D) joint kinematic and kinetic analyses. They found that nine athletes with ACL injury had significantly greater knee abduction angles and abduction moments than uninjured athletes during vertical drop jumps.[9]

Many ACL injury prevention programs have been developed based on these injury mechanisms or biomechanical data, and evidence has indicated the effectiveness of exercise.[10−16] On the other hand, the same program to prevent ACL injury is often applied to all players in a team as part of an integrated protocol. Among them, Hewett et al.[13] and Myer et al.[14,15] evaluated dynamic knee valgus using a drop jump test from a height of 31 cm and identified high-risk players. They provided jump-training programs such as wall-jumps to those at high risk with a view to improving their jumping and landing techniques. These prevention programs increased knee stability and decreased knee injury rates in female athletes. Noyes et al.[16] have also measured normalized knee separation distance using the drop-jump screening test and developed a neuromuscular training program. However, little is known about whether or not the function of the hip and foot of the other leg increases dynamic knee valgus.[17]

Claiborne et al.[18] identified a negative correlation between hip abduction peak torque and valgus knee motion during single-leg squats. Jacobs et al.[19] reported that hip abductor peak torque is lower and knee valgus is larger during landing among females than males. However, Thijs et al.[20] found no significant correlation between hip muscle strength and the amount of knee valgus moment during a forward lunge. Additionally, the conventional Trendelenburg test is an established method of evaluation for gluteus medius muscle weakness. Takacs and Hunt[21] reported that the knee adduction moment significantly increases with contralateral pelvic drop compared with level pelvis trials. The results of these studies suggested that static lower leg alignment differs from dynamic function. Therefore, our screening test uses a dynamic Trendelenburg test (DTT) to assess contralateral pelvic drop during single-leg squats and single-leg drop landings to determine dynamic hip abductor muscle dysfunction.[22]

Rear-foot eversion is thought to be coupled with tibial internal rotation not only while standing but also during the stance phase of gait or running.[23−25] Excessive pronation of the foot during exercise has frequently been cited as a risk factor for lower limb injury.[26,27] Many investigators consider excessive eversion as a rear-foot angle of greater than 4°−6°.[28−32] Some static measures such as calcaneal angle have been investigated as possible predictors of dynamic rear-foot motion.[33,34] However, static rear-foot alignment has not been found to be an accurate predictor of dynamic knee valgus. In addition, few reports describing the relationship between rear-foot alignment and dynamic knee valgus have been published to date, even though navicular drop is greater among athletes with than without ACL injuries.[35,36] Therefore, our screening test used a dynamic heel-floor test (HFT) to assess >5° of rear-foot eversion during single-leg squats and single-leg drop landings.[22]

Most investigators measure angles of knee valgus from the frontal plane on two-dimensional (2D) video-based screening images.[37,38] However, even though the dynamic alignment of knee-in and hip-out differ kinematically and kinetically, both knee valgus angles might be similar in 2D video analysis. Therefore, we measured dynamic knee valgus during single-leg squats and drop landings on 2D video images using knee-in distance (KID) to reflect knee inward displacement and hip-out distance (HOD) to reflect pelvic outward displacement. This study aimed to determine the functional association between the alignment of hip and rear-foot dynamics with dynamic knee valgus. We speculated that the amount of dynamic knee valgus would be greater in female basketball players with hip abductor dysfunction and rear-foot dynamic eversion.

## 2. Materials and methods

### 2.1. Participants

This cross-sectional study recruited 130 females, Japanese high-school basketball players (258 legs; age, 16.9 ± 0.6 years; basketball experience, 6.7 ± 2.0 years; height, 161.6 ± 5.8 cm; weight, 54.0 ± 6.3 kg) from nine high-school basketball teams. Injury history included Osgood-Schlatter disease ($n = 12$), overuse syndrome ($n = 28$), and acute injury ($n = 9$) including ACL injury ($n = 2$). The two players with a history of ACL injury had undergone reconstruction surgery over 1 year before participating in the present study. Although 37 athletes (44 legs) had experienced knee pain, they could play basketball without difficulty. The exclusion criteria comprised prior knee injury that involved surgery and pain upon performing the tasks required in the study. Thus, the players with ACL damage that had been treated by surgical reconstruction were excluded and data from 258 legs were analyzed.

The Research Ethics Committee of the School of Nursing and Rehabilitation Sciences at Showa University approved the study protocol. Written informed consent was obtained from all participants, their parents, and head coaches.

### 2.2. Procedures

The participants wore fitted dark shorts and were tested barefoot. Flat markers (9 mm in diameter) were placed at the anterior superior iliac spine (ASIS), the center of each patella, the center of the insertion of each Achilles tendon, the tibial tuberosity and the hallucis of both the right and left legs. They performed single-leg squats and single-leg drop landings from a 30 × 50-cm (height × width) box. Digital video cameras (Sony, Tokyo, Japan) were placed on stands in front and at the back of the participants and frontal images were recorded at 30 Hz. One stand was positioned about 4 m in front of each participant. The center of the front camera lens was adjusted to the height of the knees of participants while standing on a 30-cm high box. The other stand was positioned 4 m behind the box. The center of the back camera lens was positioned at the height of the insertion of the Achilles tendon.